



COMMENT



<https://doi.org/10.1057/s41599-025-05086-2>

OPEN

# Behavioural public policy for natural disaster preparedness and the role of economic experiments

Peter John Robinson<sup>1</sup>   & W. J. Wouter Botzen<sup>1</sup>

Natural disaster losses are increasing both in their frequency of occurrence and severity of impacts worldwide due to climate change and socio-economic development in disaster-prone regions. In addition to public sector investments in disaster protection infrastructure, individuals can manage these losses by implementing disaster risk reduction measures at the household level. However, a host of systematic cognitive biases may prevent the taking of cost-effective forms of risk reduction by individuals. Behavioural public policies have been proposed as a way to address these biases in order to stimulate societal natural disaster preparedness. This article highlights the role of economic experiments for developing behavioural public policies that promote disaster risk reduction actions. Based on a review of the state-of-the-art of the experimental literature, several promising directions for further research in the field are outlined. That is, avenues for further experimental research in behavioural public policy are identified. We find that more experimental research is needed to examine whether: (1) behavioural public policies can complement conventional forms of economic policy that alter financial incentives; (2) methodological advancements in the field of experimental economics can be used to further develop behavioural policies aimed at triggering natural disaster preparedness; and (3) behavioural policies are useful for addressing various under-researched field observations and realities faced by individuals at risk of natural disasters.

<sup>1</sup> Department of Environmental Economics, Institute for Environmental Studies, VU University Amsterdam, De Boelelaan 1111, Amsterdam, The Netherlands.  
✉email: [peter.robinson@vu.nl](mailto:peter.robinson@vu.nl)

## Introduction

Damages from natural disasters are increasing worldwide due to climate change and socio-economic development in disaster-prone regions (Coronese et al. 2019; Hemmati et al. 2020; Hoeppe, 2016). Households can adapt to rising climate risk by taking risk reduction measures, e.g., structural measures at one's home or emergency actions during a disaster (Porter et al. 2014; Carman and Zint, 2020). Moreover, natural disaster insurance may be purchased to cover residual risk (Mills, 2005). Nevertheless, it has been observed that individuals' cognitive biases inhibit risk reduction actions, which means that certain individuals face disaster risk unprepared (Meyer and Kunreuther, 2017). In European countries, only a quarter of climate-related catastrophe losses are insured (EIOPA, 2022). Furthermore, studies in diverse locations reveal that a substantial proportion of natural disaster-prone households lack sufficient preparedness, or are unaware of the risk they face (Al-Rousan et al. 2014; Meyer et al. 2014; Cerulli et al. 2020; Albris et al. 2020). The relevance of individual behaviour change to enhance preparedness for disaster risk caused by climate change has been stressed in recent assessments of climate change impacts and potential solutions (IPCC, 2023).

Behavioural public policy is one way to design policy interventions that leverage cognitive biases to change behaviour and raise societal preparedness for natural disasters. This article reviews the state-of-the-art economic experimental literature that evaluates behavioural policy solutions addressing lack of demand for risk reduction measures. It highlights the significant contribution of studying individuals in tightly controlled environments – afforded by experiments – for developing rigorous behavioural public policy for climate adaptation in response to natural disaster risk. In addition, the article identifies promising directions for future research in this fast-growing field. A focused review in this area is necessary since insights from other streams of behavioural public policy research, e.g., on frequent decisions like food choices (Bauer and Reisch, 2019), may not translate well to decision-making under natural disaster risks, that occur with low frequency yet high impacts. The effectiveness of behavioural public policies typically depends on the context in which they are tested (Jachimowicz et al. 2019; Mertens et al. 2022). In addition, some of the psychological barriers addressed in our review are specific to low frequency events and decisions.

A good understanding is needed of individual psychological factors at play for the design of behavioural public policy interventions, and for developing social welfare enhancing policies. That is, identifying cognitive biases that distort how individuals perceive risks can aid in how these risks are communicated (Meyer and Kunreuther, 2017). Moreover, the effectiveness and welfare implications of behavioural policies typically depend on aspects such as trust and prior beliefs related to the decision at hand, as well as underlying preferences towards risk (Bicchieri and Dimant, 2022; Smith et al. 2013; Robinson and Botzen, 2022). Policies that do not address heterogeneity of psychological factors in a population may backfire, or lead to suboptimal decisions and welfare losses among certain subgroups (Harrison and Ng, 2016).

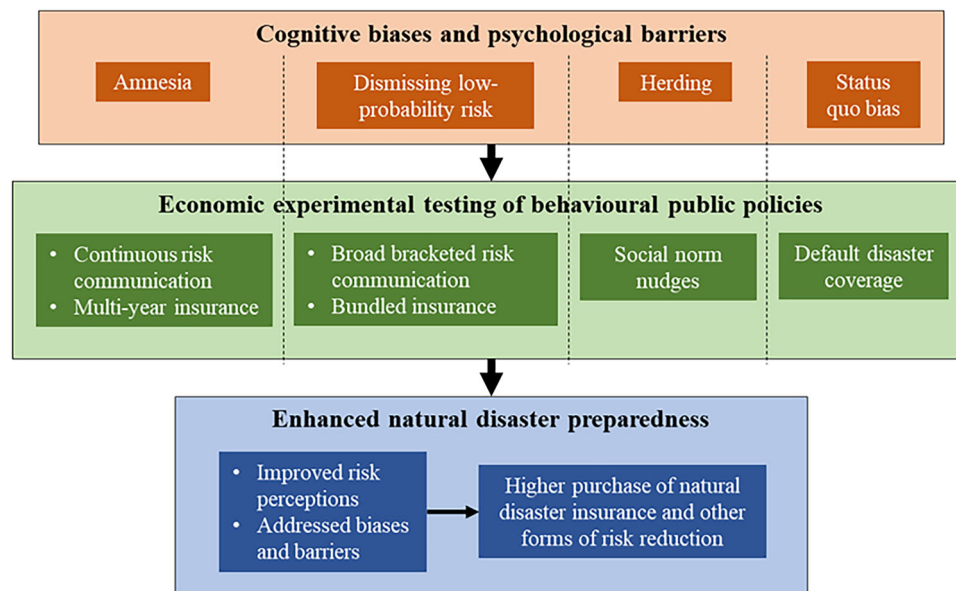
An expanding body of survey literature exists on the relationship between individual psychological variables, like risk perceptions, and natural disaster preparedness (Bubeck et al. 2012; van Valkengoed and Steg, 2019). These surveys, which are predominantly cross-sectional, are useful for providing a snapshot of behaviour and its possible psychological determinants (Hudson et al. 2020). A disadvantage is that they suffer from methodological limitations. To illustrate, it cannot be assumed that factors such as risk perceptions and behaviour are static over time. It has been observed that disaster experience inspires individuals to purchase risk reduction measures, like insurance,

but purchase rates drop a few years after this experience (Gallagher, 2014; Atreya et al. 2015). A reason for the spike in purchase after a disaster is elevated risk perceptions (Kousky, 2010). However, risk perceptions may drop after the purchase has been made due to improved protection levels. A measurement problem arises when cross-sectional surveys are conducted after the purchase of risk reduction measures, following common practice in the literature (Siegrist, 2013; Bubeck et al. 2012; Bubeck et al. 2023). Such surveys lead to a misinterpretation of causality, as they capture the response to the risk reduction measure being taken rather than the initial motivation behind the action, e.g., high perceptions of risk. Such surveys may misleadingly suggest that risk perceptions do not predict, or even negatively predict, risk reduction actions (Botzen et al. 2024).

One way to address this problem is to use longitudinal surveys of disaster risk reduction behaviour and psychological drivers of preparedness (Siegrist, 2013). Repeated sampling of individuals in longitudinal surveys can track changes in risk perceptions over time, and whether behaviour changes occur as a consequence. Nevertheless, repeated sampling is expensive and selective attrition can bias study findings (Hudson et al. 2020). Another way to address the measurement problem is to elicit risk reduction behaviour intentions in cross-sectional surveys. However, it is well-known that self-reported intentions often fail to materialize into concrete risk reduction actions, i.e., an intention-behaviour gap may exist (Osberghaus et al. 2025).

To address the intention-behaviour gap, market data investigations of behaviour, i.e., revealed preferences, in an actual natural disaster risk context can offer a way forward. Yet, in such studies one challenge is that individual-level factors, like risk perceptions, risk preferences and income, typically cannot be elicited due to data protection laws. These studies often rely on aggregated consumer behaviour, e.g., insurance purchase rates at the regional level (Kousky et al. 2018; Browne and Hoyt, 2000). For these reasons, important individual-specific variables that drive risk reduction behaviour cannot be controlled for. Furthermore, identifying relevant mediators and moderators of behavioural public policies, that include individual psychological processes, will be problematic with market data. The latter is valuable for improving the design of behavioural policies by illuminating cases where they are effective and understanding why they lead to certain outcomes.

In our view, there is an important role for economic experiments that study individual risk reduction behaviour. That is, experiments provide a number of advantages over surveys and market data examinations of risk reduction actions. They apply randomized control and treatment groups facilitating the identification of causal estimates of the effect of behavioural policies on preparedness, by holding possible confounding factors constant (Laury et al. 2009). Furthermore, experiments can study psychological determinants of natural disaster preparedness over time without encountering the aforementioned measurement problem, since these determinants can be derived prior to the preparedness choice. The coupling of this choice with monetary rewards, where incentives are structured in a way that aims to reveal individuals' true preferences (Jaspersen, 2016), may also circumvent to an extent the intention-behaviour gap, since the choice will involve real consequences. In the past this has been achieved by framing experimental choices in a natural disaster risk context, and paying a few randomly selected participants large amounts of money based on the high-consequence risk context (e.g., Kunreuther and Michel-Kerjan, 2015; Chaudhry et al. 2020; Robinson et al. 2021c). More generally, economic experiments are useful for pretesting theories of low demand for natural disaster preparedness measures and policy solutions to this problem prior to the use of field data examinations, with higher external validity (Smith, 1976; Harrison et al. 2015).



**Fig. 1** Conceptual framework of behavioural public policies that address cognitive biases and psychological barriers to enhance natural disaster preparedness.

The remainder of this article elaborates on the state-of-the-art of experimental research on individual natural disaster preparedness and behavioural public policy. This is followed by an agenda for future research in this area.

### Experimental research on natural disaster preparedness and behavioural public policy

In this section, we describe economic experiments that test for the impact of behavioural public policy on disaster preparedness decisions. The policies tested in these experiments tackle one of several cognitive biases and other psychological processes associated with low disaster preparedness described in the literature, e.g., amnesia, dismissing low-probability risk, herding and status quo bias (Meyer and Kunreuther, 2017) (Fig. 1).

**Amnesia.** While post-natural disaster recovery implies learning from previous experience to avoid future vulnerability, individuals tend to forget lessons of past disasters quickly after they have occurred (Monteil et al. 2020; Meyer and Kunreuther, 2017). This suggests that preparedness requires continuous communication about risk to prevent the forgetting process. Immersive virtual reality (VR) experiments, which combine control with heightened naturalistic context, can contribute to new forms of risk communication by conveying the catastrophic impacts of disasters on households who may not have experienced these impacts in practice (Mol, 2019). Mol et al. (2022) elicited flood risk reduction behaviour after exposing a random subgroup of their respondents to a virtual flood. They found that exposure to the flood increased investments in risk reduction, compared to a control group. However, four weeks after the intervention there was no significant difference in risk reduction investments between their treatment and control group, suggesting that the effectiveness of VR policy interventions may be short-lived.

Moreover, forgetting about natural disasters can materialize into actions that enhance financial risk, such as not renewing disaster insurance policies. To address this inclination, insurers may offer a risk-based multi-year policy that provides coverage for a fixed annual price without the possibility of cancelling the policy during the multi-year period (Kunreuther, 2021; Kleindorfer et al. 2012). An experiment by Kunreuther and Michel-

Kerjan (2015) demonstrated that individuals prefer the price stability of a multi-year contract over yearly insurance, where premiums could fluctuate based on disaster occurrence.<sup>1</sup> This preference was robust to moderate premium loading of the multi-year contract, whilst keeping the yearly insurance premium equal to the expected loss. The results suggest policymakers may raise disaster insurance penetration rates by offering multi-year contracts instead of single-year contracts.

**Dismissing low-probability risk.** Another prominent bias individuals display when facing low-probability disaster risks is their tendency to ignore risk if the associated likelihood is below some threshold level of concern (Slovic et al. 1977). This has led researchers to find ways of increasing the saliency of risk to warrant individuals' attention. Examples are experiments that showcase the effectiveness of broad bracketing low-probability events for promoting protection decisions (Chaudhry et al. 2020; Bradt, 2022). For instance, individuals tend to take risk more seriously when they are told that the cumulative probability that they experience damage to their homes from a natural disaster at least once over a 40-year time horizon is 1/3, rather than the equivalent annual likelihood of 1/100 (Keller et al. 2006). It has also been tested whether this type of framing is more or less effective at raising preparedness behaviour when combined with communication that aims to improve risk comprehension, e.g., risk ladders presenting baseline probabilities on a scale alongside other easy-to-recall risks. Robinson et al. (2021a) find that such combined risk communication has an insignificant aggregate effect on risk reduction behaviour.

Another way to deal with individuals dismissing low-probability disasters is to bundle risk with other risky events, which may impose a combined probability of one of the events occurring, that overcomes threshold levels of concern (Schwarcz 2010). Robinson and Botzen (2023) examined this strategy in the context of bundled homeowners' insurance among residents of the Netherlands and the United Kingdom. This experiment showed that the proportion of individuals with a positive risk premium for flood risk (willingness-to-pay for insurance in excess of the expected flood loss) is higher than when the risk is bundled alongside other risks in a combined insurance policy in the

United Kingdom. Homeowners' insurance currently bundles flood risk in practice here. However, no significant behavioural differences were found in the Netherlands, where flood insurance was offered as a stand-alone policy at the time of the study.

**Herdin**. Since individuals may base their decisions on others' actions (Banerjee, 1992), developing strong social norms for being well-prepared can facilitate risk reduction actions. The effect of so-called descriptive norm nudges, that inform individuals about the proportion of close referents (e.g., neighbours) who partook in risk reduction behaviour has been the focus of a few experiments on disaster preparedness. Mol et al. (2024) and Robinson and Botzen (2022) revealed to a random subgroup of their respondents the risk reduction measures taken by the majority of the referent group. Although these studies find a null main effect of the descriptive norm nudge, the latter study uncovered two subgroups among whom such a nudge is effective at raising preparedness: those whose prior beliefs are consistent with the norm, and those who trust the messenger of the norm information. Overall, this illustrates the importance of addressing individual heterogeneity in beliefs when designing behavioural public policies.

**Status quo bias**. To address individuals' reluctance to deviate from the status quo or default options, policymakers may include natural disaster coverage in standard homeowners' insurance (Kunreuther, 2021). To illustrate why defaults can be effective in this setting, it has been proposed that defaults serve as a reference point, which can change how outcomes are processed, either as gains or losses (Sunstein, 2013). In keeping with reference dependence and loss aversion (Tversky and Kahneman, 1992), individuals may be reluctant to remove natural disaster coverage from their homeowners' insurance. The possible future disaster damages may loom large compared to the savings from reduced premium payments. On the other hand, individuals whose homeowners' insurance lacks natural disaster coverage may focus more on the extra premium cost of adding such coverage, relative to the potential future damages avoided.

Kunreuther et al. (2024) found that including earthquake coverage by default in Canadian homeowners' insurance increases the probability that individuals would purchase this coverage, compared to when they must opt-in to add earthquake coverage to their homeowners' policy. A similar result was observed in Robinson et al. (2021b) for insurance against flood risk in the Netherlands, where flood insurance penetration rates and actual flood experiences were low at the time of the study. In the United Kingdom, where penetration rates are very high and flooding experience was more often reported by respondents, the study did not find a significant default effect on flood insurance demand. These findings are consistent with research showing that behavioural policy may work better when individuals are less experienced or knowledgeable about the decision at hand (Löfgren et al. 2012; List, 2003).

### Future research directions

In this section, we describe several potential avenues for further experiments on disaster preparedness based on (1) complementarities between behavioural and traditional economic policies that alter financial incentives; (2) methodological innovations made in the field of experimental economics; and (3) field observations that are yet to be studied in controlled experiments.

**Complementarities between behavioural and traditional economic policies**. Several experiments have examined whether altering financial incentives influences demand for disaster

preparedness measures. These studies and their findings are outlined here since they add to the overall literature on policy-making for disaster risk reduction tested in economic experiments. Noteworthy is that the studies have tended to explore the role of financial incentives for risk reduction decisions in isolation, which implies a knowledge gap on the complementary role of behavioural public policies in boosting preparedness. For instance, Brunette et al. (2013) and Robinson et al. (2021c) investigated whether the anticipated receipt of government compensation for disaster damages can crowd out demand for individual risk reduction measures (Browne and Hoyt, 2000). These studies showed that the removal of such payments promotes demand for disaster insurance when there is certainty associated with compensation payments. This certainty was operationalized in Robinson et al. (2021c) by introducing political factors that affect whether compensation is granted, which mimics how such payments are made in reality (Garrett and Sobel, 2003).

Other experiments have studied whether insurance design can provide a financial incentive that facilitates preparedness. For example, the level of the deductible, which is the amount of damage that the policyholder pays before insurance starts compensating, has been examined as it implies that the policyholder has 'skin in the game' and a financial incentive to take actions that limit damage (Winter, 2013). Mol et al. (2020a) used a laboratory experiment to examine the influence of various financial incentives offered by flood insurance on individual investments in flood damage mitigation measures, including deductibles. They find a positive significant influence of deductible levels on individual investments in flood damage mitigation measures. However, this effect of deductibles is not large (Mol et al. 2020a).

A more substantial financial incentive from insurance may accrue from offering policyholders a premium discount if they take actions that mitigate disaster damage (Kunreuther, 1996). If such a premium discount equals the expected value of avoided damages, it gives a financial incentive for undertaking risk reduction measures. In their experiment, Mol et al. (2020a) observed that insurance premium discounts are indeed effective in stimulating policyholders to invest in flood damage mitigation measures. In a follow up study, Mol et al. (2020b) examined if their results about the effectiveness of premium discounts that were derived from a student sample also hold among homeowners in the Netherlands, and they confirmed this was the case. These findings suggest that insurance premium discounts are an effective policy instrument for encouraging disaster risk reduction actions.

However, yearly insurance premium discounts are often smaller than the upfront costs of installing damage mitigation measures, which means it takes time before these costs are earned back by premium savings. This implies that households with budget constraints and/or myopic individuals may not invest in disaster risk reduction measures. A proposed solution is to combine insurance premium discounts with low-interest mitigation loans for financing the upfront mitigation costs (Michel-Kerjan and Kunreuther, 2011). Mol et al. (2020a) also examined the influence of such loans on damage mitigation investments, but observed an insignificant effect of this loan treatment. This null effect may occur because the short duration of their lab experiment does not adequately capture the intertemporal payoffs in real life. Hence, the effectiveness of mitigation loans can be best further analyzed in future research using field experiments.

Other financial instruments have been studied in low-income countries, like index-based insurances that payout according to predefined indices, such as rainfall. Index insurance can overcome moral hazard incentives that prevent the taking of additional risk reduction measures because payouts are not based

on damages. They also have potentially large welfare benefits in low-income countries but are usually met with low demand (Cole et al. 2013; McIntosh et al. 2019). Index insurance experiments often aim to elicit decision theory parameters or use these parameters and/or other behavioural determinants to explain decision-making processes (e.g., McIntosh et al. 2019; Cecchi et al. 2024; Hossain 2025; Dougherty et al. 2020; Shin et al. 2022). To the best of our knowledge, there are no economic experiments conducted in low-income countries with the specific objective of testing behavioural public policies for promoting the uptake of index insurance.

We propose that future research in experimental economics explicitly examines whether behavioural policies can be complemented by financial strategies. Comprehensive strategies incorporating both interventions may be needed to ensure individuals are adequately protected against disasters in the long-run. This is relevant because the sustained long-term effect of behavioural policies has been open to debate (Sanders et al. 2018; Allcott and Rogers, 2014). Moreover, financial interventions focusing on cost or moral hazard motives alone may neglect underlying cognitive biases acting as a barrier to preparedness.

### Methodological innovations in experimental economics.

Another avenue for further research in developing behavioural public policy for natural disaster preparedness may exploit the advent of neuroeconomic approaches. These methods allow for studying the brain while subjects complete controlled experimental tasks (Camerer et al. 2005). In general, neuroeconomics holds promise for identifying the impact of behavioural policies for disaster risk reduction on neural mechanisms at the root of decision-making (Sawe, 2019), assessing individual heterogeneity that may influence risk reduction behaviour, and can be used as a tool to predict market behaviour responses to climate-related policy making decisions (Genevsky and Knutson, 2015; Falk et al. 2012; Venkatraman et al. 2015).

Furthermore, future research can focus on designing and testing communication interventions that aim to keep awareness of disaster risk and coping strategies high in the absence of experiences with disaster events. VR may be a promising technology for more widespread future applicability for raising awareness through experiencing a natural hazard and the benefits of risk reduction measures in an immersive virtual environment. Future research can build on the promising pioneering work with VR experiments (Mol et al. 2022) and examine how positive significant effects on risk awareness and coping appraisals may be created that also trigger protective actions in the long-run.

**Field observations for experimental investigation.** The extent to which individuals are protected from natural disaster damage has been shown to vary over time (Michel-Kerjan et al. 2012). This may be caused by psychological processes that cause individuals to either drop their disaster insurance coverage, or not take additional risk reduction measures on top of those that are currently in place, even though they face increasing disaster risk from climate change. The latter behaviours may be due to dynamic feedback relationships between risk reduction behaviour and psychological variables that drive demand for risk reduction. For instance, individuals may be discouraged from taking additional actions if they feel sufficiently protected after implementing only minor risk reduction measures. A similar effect may arise if they perceive their previous investments in risk reduction as a waste of money because they did not experience a disaster recently.

Some efforts have been made to understand how individuals feel after investing in disaster preparedness in light of whether or not damages were experienced in the previous period

(Kunreuther and Pauly, 2018). However, most experimental research treats the temporal relationship between natural disaster risk reduction and psychological processes that influence risk reduction as static.<sup>2</sup> Therefore, future experimental research may attempt to identify cognitive biases or simplifying heuristics causing individuals to either drop their insurance coverage over time and face the next disaster uninsured, or to forgo implementation of additional measures that tackle increasing climate risk. Behavioural public policies may also be designed and tested experimentally to overcome these tendencies.

Economic experiments also allow for studying social settings, whereby individuals are provided information on the choices of other participants (Bigoni and Suetens, 2012; Santos et al. 2008). Experiments that allow for social interaction occurring across time may be especially useful for studying neighbourhood effects of natural disaster risk reduction measures. Field data suggests that individuals' structural adaptation actions are indeed affected by the observed (in)action of social peers (Osberghaus and Hünemaldt, 2023). Moreover, interesting variations of social interactions may be tested experimentally with different treatments involving levels of transparency regarding the risk reduction behaviour of individuals' neighbours.<sup>3</sup>

It is striking that most previous experimental studies focused on a specific risk reduction measure for a single natural hazard. In reality, many individuals face multiple climate risks such as wind and hailstorms and extreme precipitation, heat, and depending on their location, also river and/or coastal floods; meanwhile, various measures exist for addressing these risks. Little is known about decision processes for taking various protective measures against multi-hazard climate risks (Jansen et al. 2021), and how public policy interventions can be designed that stimulate people to prepare for multi-hazard climate risks. Moreover, previous experimental studies researched the effectiveness of single-behavioural interventions, while comprehensive strategies – combining communication and nudges – may be more effective to trigger behavioural change to adapt to multi-hazard disaster risks. The lively research field of behavioural public policy can play an important role in addressing these knowledge gaps and offer valuable insights into how to enhance societal resilience to climate change related risks.

### Data availability

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Received: 25 July 2024; Accepted: 20 May 2025;

Published online: 27 May 2025

### Notes

- 1 It may be reasonable to categorize multi-year insurance as a traditional economic intervention, since financial incentives are modified. Multi-year insurance is elaborated here as it tackles a well-defined cognitive bias.
- 2 Many experiments elicit psychological characteristics in post-experiment surveys, thereby assuming these characteristics do not develop over time in response to experimental risk reduction choices (Robinson and Botzen, 2019; Mol et al. 2020a; Markanday and Galarraaga, 2021).
- 3 There are data challenges when identifying social interaction effects, such as simultaneity, whereby two individuals may concurrently influence the behaviour of their counterpart making it difficult to identify the causal effect of the behaviour of either individual on the other (Soeteven, 2006).

### References

- Albris K, Lauta KC, Raju E (2020) Disaster knowledge gaps: Exploring the interface between science and policy for disaster risk reduction in Europe. *Int J Disaster Risk Sc* 11:1–12

- Allcott H, Rogers T (2014) The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *Am Econ Rev* 104:3003–3037
- Al-Rousan TM, Rubenstein LM, Wallace RB (2014) Preparedness for natural disasters among older US adults: A nationwide survey. *Am J Public Health* 104:506–511
- Atreya A, Ferreira S, Michel-Kerjan E (2015) What drives households to buy flood insurance? New evidence from Georgia. *Ecol Econ* 117:153–161
- Banerjee AV (1992) A simple model of herd behavior. *Q J Econ* 107:797–817
- Bauer JM, Reisch LA (2019) Behavioural insights and (un)healthy dietary choices: A review of current evidence. *J Consum Policy* 42:3–45
- Bicchieri C, Dimant E (2022) Nudging with care: The risks and benefits of social information. *Public Choice* 191:443–464
- Bigoni M, Suetens S (2012) Feedback and dynamics in public good experiments. *J Econ Behav Organ* 82:86–95
- Botzen WW, Mol JM, Robinson PJ et al. (2024) Drivers of natural disaster risk-reduction actions and their temporal dynamics: Insights from surveys during an imminent hurricane threat and its aftermath. *Risk Anal* 44:2448–2462
- Bradt J (2022) Comparing the effects of behaviorally informed interventions on flood insurance demand: An experimental analysis of ‘boosts’ and ‘nudges’. *Behav Public Policy* 6:485–515
- Browne MJ, Hoyt RE (2000) The demand for flood insurance: Empirical evidence. *J Risk Uncertain* 20:291–306
- Brunette M, Cabantous L, Couture S et al. (2013) The impact of governmental assistance on insurance demand under ambiguity: A theoretical model and an experimental test. *Theor Decis* 75:153–174
- Bubeck P, Botzen WW, Aerts JC (2012) A review of risk perceptions and other factors that influence flood mitigation behavior. *Risk Anal* 32:1481–1495
- Bubeck P, Osberghaus D, Thieken AH (2023) Explaining changes in threat appraisal, coping appraisal, and flood risk-reducing behavior using panel data from a nation-wide survey in Germany. *Environ Behav* 55:211–235
- Camerer C, Loewenstein G, Prelec D (2005) Neuroeconomics: How neuroscience can inform economics. *J Econ Lit* 43:9–64
- Carman JP, Zint MT (2020) Defining and classifying personal and household climate change adaptation behaviors. *Glob Environ Chang* 61. <https://doi.org/10.1016/j.gloenvcha.2020.102062>
- Cecchi F, Lensink R, Slingerland E (2024) Ambiguity attitudes and demand for weather index insurance with and without a credit bundle: Experimental evidence from Kenya. *J Behav Exp Finance* 41. <https://doi.org/10.1016/j.jbef.2023.100885>
- Cerulli D, Scott M, Aunap R et al. (2020) The role of education in increasing awareness and reducing impact of natural hazards. *Sustainability* 12. <https://doi.org/10.3390/su12187623>
- Chaudhry SJ, Hand M, Kunreuther H (2020) Broad bracketing for low probability events. *J Risk Uncertain* 61:211–244
- Cole S, Giné X, Tobacman J et al. (2013) Barriers to household risk management: Evidence from India. *Am Econ J - Appl Econ* 5:104–135
- Coronese M, Lamperti F, Keller K et al. (2019) Evidence for sharp increase in the economic damages of extreme natural disasters. *P Natl Acad Sci USA* 116:21450–21455
- Dougherty JP, Flatnes JE, Gallenstein RA et al. (2020) Climate change and index insurance demand: Evidence from a framed field experiment in Tanzania. *J Econ Behav Organ* 175:155–184
- EIOPA (2022) The dashboard on insurance protection gap for natural catastrophes in a nutshell. EIOPA-22/507 05 December 2022
- Falk EB, Berkman ET, Lieberman MD (2012) From neural responses to population behavior: Neural focus group predicts population-level media effects. *Psychol Sci* 23:439–445
- Gallagher J (2014) Learning about an infrequent event: Evidence from flood insurance take-up in the United States. *Am Econ J - Appl Econ* 6:206–233
- Garrett TA, Sobel RS (2003) The political economy of FEMA disaster payments. *Econ Inq* 41:496–509
- Genevsky A, Knutson B (2015) Neural affective mechanisms predict market-level microlending. *Psychol Sci* 26:1411–1422
- Harrison GW, Lau MI, Rutström EE (2015) Theory, experimental design and econometrics are complementary (and so are lab and field experiments). In: Fréchette GR, Schotter A (eds) *Handbook of Experimental Economic Methodology, Handbooks of Economic Methodology*. Oxford University Press, Oxford, UK, p 296–338
- Harrison GW, Ng JM (2016) Evaluating the expected welfare gain from insurance. *J Risk Insur* 83:91–120
- Hemmati M, Ellingwood BR, Mahmoud HN (2020) The role of urban growth in resilience of communities under flood risk. *Earth's Future* 8. <https://doi.org/10.1029/2019EF001382>
- Hoeppe P (2016) Trends in weather related disasters—Consequences for insurers and society. *Weather Clim Extremes* 11:70–79
- Hossain MS (2025) Assessing smallholder farmers' flood risk behavior and their willingness to pay for crop insurance as a risk coping strategy in northern Bangladesh. *Nat Hazards* 121:4191–4217
- Hudson P, Thieken AH, Bubeck P (2020) The challenges of longitudinal surveys in the flood risk domain. *J Risk Res* 23:642–663
- IPCC (2023) Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland
- Jachimowicz JM, Duncan S, Weber EU et al. (2019) When and why defaults influence decisions: A meta-analysis of default effects. *Behav Public Policy* 3:159–186
- Jansen PC, Snijders CC, Willemsen MC (2021) Determinants of domestic risk prevention behavior: The importance of separating effects within-persons and between-persons. *Risk Anal* 41:929–943
- Jaspersen JG (2016) Hypothetical surveys and experimental studies of insurance demand: A review. *J Risk Insur* 83:217–255
- Keller C, Siegrist M, Gutscher H (2006) The role of the affect and availability heuristics in risk communication. *Risk Anal* 26:631–639
- Kleindorfer PR, Kunreuther H, Ou-Yang C (2012) Single-year and multi-year insurance policies in a competitive market. *J Risk Uncertain* 45:51–78
- Kousky C (2010) Learning from extreme events: Risk perceptions after the flood. *Land Econ* 86:395–422
- Kousky C, Michel-Kerjan EO, Raschky PA (2018) Does federal disaster assistance crowd out flood insurance? *J Environ Econ Manag* 87:150–164
- Kunreuther H (1996) Mitigating disaster losses through insurance. *J Risk Uncertain* 12:171–187
- Kunreuther H (2021) Improving the national flood insurance program. *Behav Public Policy* 5:318–332
- Kunreuther H, Conell-Price L, Li B et al. (2024) Influence of a private-public risk pool and an opt-out framing on earthquake protection demand for Canadian homeowners in Quebec and British Columbia. *Risk Anal* 44:2008–2024
- Kunreuther H, Michel-Kerjan E (2015) Demand for fixed-price multi-year contracts: Experimental evidence from insurance decisions. *J Risk Uncertain* 51:171–194
- Kunreuther H, Pauly MV (2018) Dynamic insurance decision-making for rare events: The role of emotions. *Geneva Pap R I-Iss P* 43:335–355
- Laury SK, McInnes MM, Swarthout JT (2009) Insurance decisions for low-probability losses. *J Risk Uncertain* 39:17–44
- List JA (2003) Does market experience eliminate market anomalies? *Q J Econ* 118:41–71
- Löfgren Å, Martinsson P, Hennlock M et al. (2012) Are experienced people affected by a pre-set default option—Results from a field experiment. *J Environ Econ Manag* 63:66–72
- Markanday A, Galarraga I (2021) The cognitive and experiential effects of flood risk framings and experience, and their influence on adaptation investment behaviour. *Climate Risk Management* 34. <https://doi.org/10.1016/j.crm.2021.100359>
- McIntosh C, Povel F, Sadoulet E (2019) Utility, risk and demand for incomplete insurance: Lab experiments with Guatemalan co-operatives. *Econ J* 129:2581–2607
- Mertens S, Herberz M, Hahnel UJ, Brosch T (2022) The effectiveness of nudging: A meta-analysis of choice architecture interventions across behavioral domains. *Proc Natl Acad Sci USA* 119. <https://doi.org/10.1073/pnas.2107346118>
- Meyer RJ, Baker J, Broad K et al. (2014) The dynamics of hurricane risk perception: Real-time evidence from the 2012 Atlantic hurricane season. *B Am Meteorol Soc* 95:1389–1404
- Meyer R, Kunreuther H (2017) *The ostrich paradox: Why we underprepare for disasters*. University of Pennsylvania Press
- Michel-Kerjan E, Kunreuther H (2011) Redesigning flood insurance. *Science* 333:408–409
- Michel-Kerjan E, Lemoyne de Forges S, Kunreuther H (2012) Policy tenure under the US national flood insurance program (NFIP). *Risk Anal* 32:644–658
- Mills E (2005) Insurance in a climate of change. *Science* 309:1040–1044
- Mol JM (2019) Goggles in the lab: Economic experiments in immersive virtual environments. *J Behav Exp Econ* 79:155–164
- Mol JM, Botzen WW, Blasch JE (2020a) Risk reduction in compulsory disaster insurance: Experimental evidence on moral hazard and financial incentives. *J Behav Exp Econ* 84. <https://doi.org/10.1016/j.socsc.2019.101500>
- Mol JM, Botzen WW, Blasch JE (2020b) Behavioral motivations for self-insurance under different disaster risk insurance schemes. *J Econ Behav Organ* 180:967–991
- Mol JM, Botzen WW, Blasch JE (2022) After the virtual flood: Risk perceptions and flood preparedness after virtual reality risk communication. *Judgm Decis Mak* 17:189–214
- Mol JM, Botzen WW, Blasch JE et al. (2024) All by myself? Testing descriptive social norm-nudges to increase flood preparedness among homeowners. *Behav Public Policy* 8:121–153
- Monteil C, Barclay J, Hicks A (2020) Remembering, forgetting, and absencing disasters in the post-disaster recovery process. *Int J Disast Risk Sc* 11:287–299
- Osberghaus D, Botzen WW, Kesternich M (2025) The intention-behavior gap in climate change adaptation: Evidence from longitudinal survey data. *Ecol Econ* 231. <https://doi.org/10.1016/j.ecolecon.2025.108543>

- Osberghaus D, Hünemaldt V (2023) Neighborhood effects in climate change adaptation behavior: Empirical evidence from Germany. *Reg Environ Change* 23. <https://doi.org/10.1007/s10113-023-02083-6>
- Porter JJ, Dessai S, Tompkins EL (2014) What do we know about UK household adaptation to climate change? A systematic review. *Clim Change* 127:371–379
- Robinson PJ, Botzen WW (2019) Determinants of probability neglect and risk attitudes for disaster risk: An online experimental study of flood insurance demand among homeowners. *Risk Anal* 39:2514–2527
- Robinson PJ, Botzen WW (2022) Setting descriptive norm nudges to promote demand for insurance against increasing climate change risk. *Geneva Pap R I-Iss P* 47:27–49
- Robinson PJ, Botzen WW (2023) Can we nudge insurance demand by bundling natural disaster risks with other risks? *J Behav Econ Policy* 7:39–46
- Robinson PJ, Botzen WW, Duijndam S et al. (2021a) Risk communication nudges and flood insurance demand. *Clim Risk Manage* 34. <https://doi.org/10.1016/j.crm.2021.100366>
- Robinson PJ, Botzen WW, Kunreuther H et al. (2021b) Default options and insurance demand. *J Econ Behav Organ* 183:39–56
- Robinson PJ, Botzen WW, Zhou F (2021c) An experimental study of charity hazard: The effect of risky and ambiguous government compensation on flood insurance demand. *J Risk Uncertain* 63:275–318
- Sanders M, Snijders V, Hallsworth M (2018) Behavioural science and policy: Where are we now and where are we going? *Behav Public Policy* 2:144–167
- Santos FC, Santos MD, Pacheco JM (2008) Social diversity promotes the emergence of cooperation in public goods games. *Nature* 454:213–216
- Sawe NIK (2019) Adapting neuroeconomics for environmental and energy policy. *Behav Public Policy* 3:17–36
- Schwarcz D (2010) Insurance demand anomalies and regulation. *J Consum Aff* 44:557–577
- Shin S, Magnan N, Mullally C et al. (2022) Demand for weather index insurance among smallholder farmers under prospect theory. *J Econ Behav Organ* 202:82–104
- Siegrist M (2013) The necessity for longitudinal studies in risk perception research. *Risk Anal* 33:50–51
- Slovic P, Fischhoff B, Lichtenstein S et al. (1977) Preference for insuring against probable small losses: Insurance implications. *J Risk Insur* 44:237–258
- Smith VL (1976) Experimental economics: Induced value theory. *Am Econ Rev* 66:274–279
- Smith NC, Goldstein DG, Johnson EJ (2013) Choice without awareness: Ethical and policy implications of defaults. *J Public Policy Mark* 32:159–172
- Soetevent AR (2006) Empirics of the identification of social interactions; an evaluation of the approaches and their results. *J Econ Surv* 20:193–228
- Sunstein CR (2013) Deciding by default. *U Penn Law Rev* 162:1–57
- Tversky A, Kahneman D (1992) Advances in prospect theory: Cumulative representation of uncertainty. *J Risk Uncertain* 5:297–323
- van Valkengoed AM, Steg L (2019) Meta-analyses of factors motivating climate change adaptation behaviour. *Nat Clim Change* 9:158–163
- Venkatraman V, Dimoka A, Pavlou PA et al. (2015) Predicting advertising success beyond traditional measures: New insights from neurophysiological methods and market response modeling. *J Mark Res* 52:436–452
- Winter RA (2013) Optimal insurance contracts under moral hazard. In: Dionne G (ed) *Handbook of Insurance*, 2nd edn. Springer, New York, p 205–230

## Acknowledgements

This study received funding from the EU PIISA grant number. 10112841 and EU ERC INSUREADAPT grant number. 101086783.

## Author contributions

Peter John Robinson conceptualized the study and wrote the manuscript. W. J. Wouter Botzen contributed to conceptualization and wrote specific parts of the manuscript on financial incentives tested in economic experiments as well as future research on disaster preparedness under multi-hazard disaster risks.

## Competing interests

The corresponding author is an editorial board member. The authors declare no other competing interests.

## Ethical approval

Ethical approval was not required as the study did not involve human participants.

## Informed consent

This article does not contain any studies with human participants performed by any of the authors.

## Additional information

**Correspondence** and requests for materials should be addressed to Peter John Robinson.

**Reprints and permission information** is available at <http://www.nature.com/reprints>

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

© The Author(s) 2025